Spatial Access to Sterile Syringes and the Odds of Injecting with an Unsterile Syringe among Injectors: A Longitudinal Multilevel Study

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ABSTRACT *Despite the 2010 repeal of the ban on spending federal monies to fund syringe exchange programs (SEPs) in the USA, these interventions—and specifically SEP site locations—remain controversial. To further inform discussions about the location of SEP sites, this longitudinal multilevel study investigates the relationship between spatial access to sterile syringes distributed by SEPs in New York City (NYC) United Hospital Fund (UHF) districts and injecting with an unsterile syringe among injectors over time (1995–2006). Annual measures of spatial access to syringes in each UHF district (N=42) were created using data on SEP site locations and site-specific syringe distribution data. Individual-level data on unsterile injecting among injectors (N=4,067) living in these districts, and on individual-level covariates, were drawn from the Risk Factors study, an ongoing cross-sectional study of NYC drug users. We used multilevel models to explore the relationship of district-level access to syringes to the odds of injecting with an unsterile syringe in >75% of injection events in the past 6 months, and to test whether this relationship varied by district-level arrest rates (per 1,000 residents) for drug and drug paraphernalia possession. The relationship between district-level access to syringes and the odds of injecting with an unsterile syringe depended on district-level arrest rates. In districts with low baseline arrest rates, better syringe access was associated with a decline in the odds of frequently injecting with an unsterile syringe (AOR, 0.95). In districts with no baseline syringe access, higher arrest rates were associated with increased odds of frequently injecting with an unsterile syringe (AOR, 1.02). When both interventions were present, arrest rates eroded the protective effects of spatial access to syringes. Spatial access to syringes in small geographic areas appears to reduce the odds of injecting with an unsterile syringe among local injectors, and arrest rates elevate these odds. Policies and practices that curtail syringe flow in geographic areas (e.g., restrictions on SEP locations or syringe distribution) or that make it difficult for injectors to use the sterile syringes they have acquired may damage local injectors' efforts to reduce HIV transmission and other injection-related harms.*

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Despite the 2010 repeal of the ban on spending federal monies to fund syringe exchange programs (SEPs) in the USA,¹ these interventions remain controversial in many localities. This controversy often extends to the sites where SEPs operate.²⁻⁴ Local business leaders and residents, for example, have protested the establishment and ongoing operation of SEPs in their midst.³ The 2010 appropriations law that lifted the federal ban codified this controversy: the law stipulates that, to be eligible for federal funding, SEPs must first receive local police department and public health department approval on the location of their sites.¹ This paper is thus designed to further inform ongoing debates about spatial access to SEPs. Specifically, we analyze 12 years of data from one city (New York City) that has experienced a scale-up in SEP presence, and explore the relationship between geographic and temporal variations in the volume of syringes distributed by SEPs and local injectors' ability to inject with a sterile syringe. Before presenting our methods, we describe our conceptualization of SEPs, and review the conceptual model guiding our analyses.

CONCEPTUALIZING SEPS AS STRUCTURAL INTERVENTIONS

While SEPs are frequently conceptualized as structural interventions—⁵⁻¹⁰ that is, as interventions that alter the “context within which health is produced and reproduced”—^{11(p. 59)} the extent to which studies have operationalized this conceptualization has been uneven. SEPs' direct effects on program participants have been extensively documented: individuals who routinely personally acquire syringes and other harm reduction materials from an SEP engage in less receptive syringe sharing (RSS) and have lower rates of HIV.¹²⁻¹⁸ In contrast, the ways in which SEPs alter the contexts in which *non*-SEP-participants inject drugs (i.e., SEPs' *indirect* effects) have received substantially less empirical attention. One mechanism through which SEPs indirectly affect behavior is by increasing the volume of sterile syringes circulating within communities.⁵ SEP participants often relay sterile syringes to non-participants: participants report redistributing $\geq 50\%$ of the sterile syringes they acquire from SEPs to other injectors.¹⁹⁻²¹ This mass redistribution can happen through secondary syringe exchange, in which SEP participants transfer sterile syringes to their network members, and through satellite syringe exchange, when SEP participants travel to an underserved area to distribute or sell syringes to individuals who are outside their network.²²

Most studies of SEPs' effects on injection practices, however, draw their samples from the pool of program participants. These studies thus substantially underestimate these programs' impacts on RSS in injecting populations. Notably, in a 2005 study, Huo and colleagues sampled both SEP participants and non-participants to explore the impact of secondary and satellite exchange, and concluded that, while participants reaped the greatest benefits of the SEP, non-participants who received sterile syringes from SEP participants had a lower odds of engaging in RSS than injectors who did not.¹⁹ Another study corroborates these findings.²³

CONCEPTUALIZING SEPS AS SPATIAL INTERVENTIONS

Corollary to the above, we also conceptualize SEPs as structural interventions that exert their strongest effects in geographic areas closest to program sites.¹⁰ In an

analysis of 1994–1996 Risk Factors data, Rockwell and colleagues found that injectors living within 10 of an SEP were 2.89 times more likely to report going to an SEP in the past 6 months than other injectors, and about half as likely to have engaged in RSS during the last injection.²⁴ Related studies have reached similar conclusions.^{25,26} Individuals who live near SEPs thus appear to be more likely to use these programs regularly. Given that SEP participants may be more likely to form relationships with injectors living near them,²⁷ non-participants who live near SEPs may also be likely to reap the benefits of secondary exchange.

SEPS AND THE RISK ENVIRONMENT: A CONCEPTUAL MODEL

The risk environment model focuses on the ways that social situations, structures, and places interact to produce vulnerability to HIV among injectors.^{8,28–30} The risk environment is defined as “...the space—whether social or physical—in which a variety of factors exogenous to the individual interact to affect the chances of HIV transmission.”^{8(p.1027)} There are different types of factors (i.e., physical, social, economic, and policy) which operate on different levels (i.e., micro and macro).³⁰ In areas where SEPs are legal, spatial access to syringes flowing from SEPs has been conceptualized as a protective micro-level policy factor.³⁰

This model posits that risk environments are produced by the *interplay* of many factors operating both within and across levels.^{8,28–30} As discussed above, the impact of SEPs on injection practices may vary according to whether injectors personally go to SEP sites.¹⁹ Evidence suggests that at least three other factors may also interact with spatial access to syringes to shape injection practices:

Local Drug-Related Arrest Rates. Local drug-related law enforcement activities targeting drug users impede injectors’ efforts both to go to SEPs, and to inject safely.^{31–41} The relationship between spatial access to syringes and injecting with an unsterile syringe may be attenuated in heavily policed settings.

Spatial Access to Pharmacies Selling Syringes over the Counter. Pharmacies that sell syringes over the counter (OTC) provide an alternative, reliable source of sterile syringes.^{42,43} Injectors with better spatial access to pharmacies selling OTC syringes are more likely to inject with sterile syringes.²⁵ The relationship between spatial access to syringes distributed via SEPs and injecting with an unsterile syringe may be attenuated in areas that have better spatial access to these pharmacies.

Individual Race/Ethnicity. Williams et al. found that the inverse relationship between travel distance to an SEP and RSS is stronger for Latino injectors than for White and Black injectors.²⁶ The relationship between spatial access to syringes and injecting with an unsterile syringe may vary across racial/ethnic groups.

This multilevel, longitudinal analysis investigates the relationship between spatial access to sterile syringes, distributed by SEPs, and the odds of injecting with an unsterile syringe in NYC United Hospital Fund (UHF) districts over time (1995–2006). We explore whether this relationship varies by local drug-related arrest rates, spatial access to OTC pharmacies, and by individual injector’s race/ethnicity and SEP participation. NYC experienced variations in SEP presence, drug-related arrest rates, and OTC pharmacy access during the study period. This study period starts 3 years after state policy began permitting select SEPs to operate legally, and spatial

access to SEP sites increased thereafter.⁴⁴ Mayor Giuliani implemented an increasingly active “zero tolerance” policy toward illegal substance use between 1995 and 2001, a policy that has subsequently been de-emphasized.⁴⁵ In 2001, it became legal for NYC-based pharmacies to sell ≤ 10 syringes without a prescription, provided that pharmacies registered with the state health department.⁴⁶ This initiative was called the “Expanded Syringe Access Program” (ESAP).

METHODS

Units of Analysis

This study has three nested units of analysis: individuals, study year, and NYC UHF districts. Individuals were injectors taking part in the Risk Factors for AIDS among Intravenous Drug Users study (DA003574, Principal Investigator: Dr. Don Des Jarlais). Risk Factors is an ongoing series of cross-sectional studies that recruits participants from one of NYC’s largest detoxification facilities.⁴⁷ To be included in this analysis, Risk Factors participants had to report injecting drugs in the past 6 months; be interviewed between 1995 and 2006; be ≥ 18 years old; and report a valid NYC ZIP code. Homeless individuals were linked to ZIP codes via the street intersection closest to where they had slept most in the past 6 months; 4,178 Risk Factors participants met these criteria. Annual Risk Factors data were merged to create a database spanning 1995–2006.

We used participant ZIP code data to link participants to UHF districts. NYC has 42 UHF districts, each of which consists of three to nine adjacent ZIP code areas that have similar sociodemographic profiles.⁴⁸ The NYC Health Department uses UHF districts to track and analyze local patterns of health outcomes and service delivery.⁴⁹ In 1995, the median district population size was 179,189 (range, 28,739–428,867).⁵⁰

Measures

District-Level Measures The main district-level exposure was spatial access to sterile syringes flowing from SEPs. We created this measure in three steps:

1. Geocoding SEP sites: The NYS Health Department shared annual data on the street address of each legal SEP site. All SEP sites were geocoded to their latitude and longitude. Sites on van routes and walkabouts were geocoded to the nearest intersection.
2. Modeling syringe flow from each site: The NYS Health Department and local SEPs shared data on the number of syringes distributed by each site annually. Our model assumed that all syringes were distributed within 1 mile (measured along the road network) of each SEP source, and that the distribution of syringes within this 1-mile buffer decayed exponentially with distance. Given that this is a new line of inquiry, we calculated two syringe flow measures that used different decay parameters, implemented across concentric buffers of one tenth of a mile each (Figure 1).⁵¹ When the more gradual decay function was applied, 13% of syringes were distributed within one tenth of a mile of the SEP site, and approximately 59% of syringes were distributed within 0.5 miles. When the steeper decay function was applied, 17% of syringes were distributed within one tenth of a mile of the SEP site, and approximately 67% of syringes were distributed within 0.5 miles.
3. Calculating district-level syringe access: the concentric circle buffers were then converted to raster format, and each 10×10 foot raster cell was assigned a syringe

FIGURE 1. Creating the district-level measure of spatial access to syringes distributed by syringe exchange programs.

count estimate based on the corresponding concentric circle values. Raster cell values were averaged within districts to generate a district-wide average of distributed syringes.

The two resulting measures provide area-weighted averages of the number of syringes flowing into each UHF district from SEPs, calculated using different decay functions, for each year of the study period.

Methods used to measure ESAP pharmacy access and drug-related arrest rates have been described elsewhere,^{10,25} and so we summarize them here. We obtained the addresses of all ESAP pharmacies operating each year between 2001 and 2006 from the State Health Department; 97% of these 1,316 pharmacies were geocoded. Our measure of ESAP pharmacy access captured the percent of each district's surface area within a mile (along the road network) of ≥ 1 ESAP pharmacy.

We obtained annual data on the number of arrests occurring in NYC in which at least one charge was for possession of any illegal drug or for paraphernalia possession from the NYS Division of Criminal Justice Services. For each district and year, we divided this number by the number of district residents aged 15–64, and calculated the annual district-level arrest rate per 1,000 residents.

Past research has concluded that local racial/ethnic composition is related to the odds that an individual will engage in RSS.⁵² We analyzed US census data to calculate the percent of district residents who were non-Hispanic White during each year of the study period.

Time. We expressed time in several ways. Study year ranged from 0 (1995) to 11 (2006). The variable “years since ESAP began” was 0 during the years 1995–2000, and ranged from 1 to 6 between 2001 and 2006. “ESAP era” was a dichotomous variable denoting whether the ESAP sales were legal that year.

Individual-Level Measures. The outcome “injecting with an unsterile syringe” included RSS and personal syringe re-use in the prior 6 months, a measure that consonant with public health guidelines to use a new sterile syringe for each injection.⁵³ RSS has well-established links to HIV and HCV transmission;^{17,54} personal syringe re-use may increase the risk of endocarditis, abscesses, and cellulitis.^{55,56} This outcome was operationalized as an ordinal variable with three levels: injecting with an unsterile syringe in $\leq 25\%$ of injection events during the past 6 months; in 26–74% of injection events; and in $\geq 75\%$ of injection events.

Possible individual-level confounders included injection frequency, years since first injection, sexual orientation, gender, homelessness, marital status, educational attainment, age, and self-reported HIV serostatus.^{57–63} Though the Risk Factors study tested participants for HIV, we used self-reported HIV status because individuals who know they are HIV-positive engage in less injection-related risk behaviors.⁴⁷ Individual race/ethnicity and SEP participation (i.e., going to an SEP in the past 6 months) were treated as possible effect modifiers. All covariates were binary except years since first injection, which was continuous.

Analysis

We used exploratory data analysis methods to describe temporal trajectories of district-level spatial access to sterile syringes.⁶⁴ We modeled temporal changes in the cumulative odds of injecting with an unsterile syringe with a three-level hierarchical generalized linear model in which individuals were nested in time and time was nested in UHF districts.⁶⁵ In this growth curve model, as in all models, we controlled for temporal variations in the composition of the Risk Factors sample. To build the optimal model describing the relationship between spatial access to syringes and the cumulative odds of injecting with an unsterile syringe, we identified the best-fitting variance/covariance structure, and tested possible cross-level and intra-level interactions.^{65,66} Because type II errors are likely when testing interaction effects in non-experimental designs, interactions were deemed significant when $p < 0.10$.^{67,68} This cut-point has been increasingly used in research on the social determinants of health.^{69–73} To linearize their relationship to the outcome, we logged the syringe access and ESAP access variables. Individual-level continuous variables were mean-centered. Time-varying continuous variables were centered at their initial value.^{65,66} Since no districts had arrest rates of zero in 1995, we constructed the baseline drug-related arrest rate variable so that it equaled zero when arrest rates were at their lowest.

RESULTS

Approximately one third of the Risk Factors participants included in these analyses were homeless, 80% were men, and about half were Latino/a (Table 1). Forty-three

percent reported injecting more than four times a day, and half had been injecting for at least 14 years. Thirty-eight percent of the sample had been to an SEP at least once in the past 6 months. One third reported injecting with an unsterile syringe during $\geq 75\%$ of injection events in the past 6 months; approximately 20% reported doing so during 26–74% of injection events.

Turning to the districts where these injectors lived, the median drug-related arrest rate in 1995 was 8.75 per 1,000 adults (Table 1). The median drug-related arrest rate in 2006 was similar to the 1995 value. Between 1995 and 2006, however, the median drug-related arrest rate changed substantially, increasing by 50% between 1995 and 2000 and then declining thereafter (data not shown). Spatial access to ESAP pharmacies was high in the inaugural year of this initiative: in half of the districts in 2001, at least 83.27% of the district surface area was within 1 mile of such a pharmacy; the median increase in ESAP access between 2001 and 2006 was slight.

There was substantial variation in spatial access to syringes acquired through SEPs, both across districts and over time. Turning to the distribution of the “gradual decay” syringe access measure across districts in 1995, we find that half of the districts ($N=21$) had no access to sterile syringes distributed by SEPs, as assessed by this measure (Table 2). Syringe access in the remaining 21 districts, however, varied considerably: in 1995 the area-weighted average number of syringes flowing into each district ranged from approximately 22 to 58,962. This variation was particularly pronounced in the fourth quartile: the access variable’s maximum value (58,961.60) was 68 times greater than the value of the 75th percentile (857.94). The distribution of the syringe access variable calculated using the “steeper decay” formula followed a similar pattern, though at a smaller scale (Table 2).

To explore subsequent temporal changes in the area-weighted average number of syringes flowing into each district (calculated using the “gradual decay” measure), we tracked the median annual change scores (Table 1) for three groups of districts: those that had no syringe access in 1995 ($N=21$); those districts in the 3rd quartile of this syringe access variable in 1995 ($N=10$); and districts in the fourth quartile of this variable in 1995 ($N=11$). Districts that had no syringe access in 1995 essentially continued to have no access throughout the study period (Figure 2). Districts in the fourth quartile at baseline experienced substantial changes in access over time: the annual median change score in this group rose from 1,703 in 1996 to 6,000 in 2000, and then declined to 1,744 by 2006. Syringe access in districts in the third quartile also peaked in 2000 and then fell, though the magnitudes of these changes were more modest. Figure 3 depicts a snapshot of syringe access values in one year, 2000. Change scores for the “steeper decay” syringe access measure followed a similar pattern (data not shown).

The optimal growth curve model for our outcome indicates substantial change over time in the odds of injecting with an unsterile syringe among Risk Factors participants (model A in Table 3). The probability of injecting with an unsterile syringe $>25\%$ of the time in the past 6 months was 0.50 in 1995; the probability of injecting with an unsterile syringe $\geq 75\%$ of the time during this period was 0.66.* (Relationships between predictors and our outcome are identical regardless of whether the outcome is injecting with an unsterile syringe $\geq 75\%$ of the time, or injecting with an unsterile syringe $>25\%$ of the time. Hereafter, we therefore report

*Probabilities are calculated as $1/(1+(\exp(-\beta)))$. Betas are the natural logs of the AORs presented in the tables.

TABLE 1 Description of injecting participants in the Risk Factors sample (*N*=4,067) and of the New York City UHF districts where they lived (*N*=42)

Characteristics	<i>N</i> (%) or median (IQR)
Frequency with which injected with an unsterile syringe in the past 6 months	
≥75% of injection events	1,360 (33.44%)
26–74% of injection events	768 (18.88%)
≤25% of injection events	1,939 (47.68%)
Age (years)	
18–30	776 (19.08%)
31–40	1556 (38.26%)
>40	1,735 (42.66%)
Women	846 (20.80%)
Race	
Latino/a	2,087 (51.32%)
Black	848 (20.85%)
White	1,132 (27.83%)
Homeless	1,374 (33.78%)
Lesbian/gay/bisexual	439 (10.79%)
Married or living as married	724 (17.80%)
HIV-positive (self-report)	463 (11.38%)
Education	
Less than high school diploma	2,076 (51.04%)
High school graduate	1,061 (26.09%)
Post-high-school education	930 (22.87%)
Injection frequency	
<1 time a day	835 (20.53%)
1–3 times per day	1,496 (36.78%)
≥4 times per day	1,736 (42.69%)
Number of years since first injection	14 (5, 25)
Gone to an SEP in the past 6 months	1,606 (38.40%)
District-level characteristics ^a	
Drug-related arrest rates per 1,000 adults	
Baseline (1995)	8.75 (2.80, 15.17)
Change in arrest rates between 1995 and 2006	0.59 (–2.99, 2.42)
Percent of district surface area within 1 mile of an ESAP pharmacy	
When ESAP first legalized (2001)	83.27 (63.26, 95.15)
Change in access between 2001 and 2006	2.70 (0.14, 8.90)
Percent of district residents who were non-Hispanic White	
Baseline (1995)	47.28 (13.26, 66.94)
Change between 1995 and 2006	–5.53 (–11.98, –1.03)

^aDetailed descriptions of the syringe access variables are presented in Table 2 and Figure 1.
Change scores were calculated by subtracting the variable’s 1995 value from the value for each subsequent year.

TABLE 2 Central tendency and dispersion of two measures of district-level syringe access in 1995

Syringe access measure	Minimum	25th percentile	Median	75th percentile	Maximum
Gradual decay measure	0	0	0	857.94	58,961.60
Steeper decay measure	0	0	0	714.30	53,121.20

FIGURE 2. Median change scores (since 1995) in spatial access to sterile syringes distributed by legal syringe exchange programs in New York City UHF districts over time (1996–2006), categorized in terms of baseline (1995) syringe access.

results using only the 75% cut-point, and refer to this outcome as “frequently injecting with an unsterile syringe.”) The combination of the expressions of time (number of years since the study began, number of years since ESAP began, and ESAP era) describe the subsequent trajectory of this variable. Specifically, an AOR of 1.12 ($p < 0.0001$) for the main effects of the study year variable indicates that the odds of frequently injecting with an unsterile syringe increased by 12% annually between 1995 and 2000. Subsequently, the ESAP-related variables alter both the elevation and the slope of this trajectory, and indicate that the odds of this outcome declined substantially in 2001, and then returned to approximately their 2000 level in 2002/2003. These odds declined during the remainder of the study period, and the rate of decline accelerated with each passing year (AOR, 0.89; $p < 0.0001$).

The optimal predictive model suggests that the relationship between spatial access to syringes (assessed using the “gradual decay” measure) and the odds of frequently injecting with an unsterile syringe depend on local drug-related arrest rates (model B, Table 3). Specifically, in districts with low drug-related arrest rates in 1995, on average a one-unit difference in the log of this syringe access variable across districts at baseline was inversely associated with a 5% (AOR, 0.95; $p = 0.004$) difference in the odds of frequently injecting with an unsterile syringe. In districts with no syringe access in 1995, a one-unit difference in baseline drug-related arrest rates across districts was positively associated with a 2% ($p = 0.06$) difference in the odds of this outcome.* Notably, however, the AOR for the interaction of syringe access and drug-related arrest rates in 1995 (AOR, 0.99; $p = 0.04$) indicates that the adverse relationship between arrest rates and unsterile injecting was attenuated in districts with better spatial access to syringes (and, conversely, that arrest rates attenuate SEPs’ protective efforts).

*As discussed in the methods section, we have used $p < 0.10$ as our cut-point for statistical significance when considering interactions of two geospatial exposures.

FIGURE 3. Area-weighted average number of syringes in each New York City United Hospital Fund district in 2000.

While there was no relationship between changes in drug-related arrest rates over time and the odds of frequently injecting with an unsterile syringe, the relationship between increasing syringe access over time and this outcome approached significance (AOR, 0.94; $p=0.09$), and suggests a protective relationship in which a one-unit increase in the log of syringe access over time is associated with a 6% decline in the odds of frequently injecting with an unsterile syringe.

While the interaction between ESAP pharmacy access and syringe access was not statistically significant, ESAP access independently predicted the odds of injecting with an unsterile syringe. Specifically, a one-unit increase in the log of spatial access to an ESAP pharmacy over time was associated with a 14% decline in the odds of frequently injecting with an unsterile syringe (AOR, 0.86; $p=0.002$).

We found no evidence that the relationship between spatial access to syringes and unsterile injecting varied by individual race/ethnicity or SEP participation (data not shown). We did not retain SEP participation in subsequent models as a covariate because it likely lies in the causal pathway between spatial access to syringes and unsterile injecting.

TABLE 3 Multilevel regression of spatial access to syringes acquired from syringe exchange programs (SEPs) in New York City UHF Districts ($N=42$) on the odds of injecting with an unsterile syringe in the past 6 months among individual injectors ($N=4,067$) over time (1995–2006)

Predictors	Model A growth curve model AOR (p value)	Model B “gradual decay” syringe access measure AOR (p value)	Model C “steeper decay” syringe access measure AOR (p value)
Intercept 1 ^a	0.83 (0.61)	0.82 (0.75)	0.84 (0.77)
Intercept 2 ^b	1.94 (0.04)	1.93 (0.28)	1.96 (0.27)
Age (ref: >40 years old)			
18–30 years old	1.17 (0.18)	1.18 (0.17)	1.18 (0.17)
31–40 years old	1.10 (0.28)	1.10 (0.28)	1.10 (0.28)
Sex	0.80 (0.01)	0.80 (0.008)	0.80 (0.008)
Race (ref=Latino/a)			
Black	0.99 (0.99)	0.97 (0.75)	0.97 (0.75)
White	1.32 (0.001)	1.27 (0.007)	1.27 (0.007)
Homeless	1.24 (0.003)	1.25 (0.003)	1.25 (0.003)
Lesbian/gay/bisexual	1.15 (0.20)	1.16 (0.18)	1.16 (0.18)
HIV-positive (self-report)	0.98 (0.86)	1.04 (0.72)	0.97 (0.73)
Injection frequency (ref: less than daily)			
1–3 times/day	1.91 (<0.0001)	1.87 (<0.0001)	1.87 (<0.0001)
≥4 times/day	2.68 (<0.0001)	2.65 (<0.0001)	2.65 (<0.0001)
Married or living as married	0.78 (0.005)	0.78 (0.004)	0.78 (0.004)
Education (ref=less than high school diploma)			
High school graduate	0.89 (0.14)	0.90 (0.15)	0.90 (0.15)
Post-high-school education	0.72 (0.0002)	0.72 (0.0002)	0.72 (0.0002)
Number of years since first injection	1.00 (0.99)	1.00 (0.95)	1.00 (0.95)
Time-varying predictors			
Years since study began	1.12 (<0.0001)	1.14 (<0.0001)	1.14 (<0.0001)
Years since ESAP started	3.00 (<0.0001)	6.04 (<0.0001)	6.05 (<0.0001)
Interaction of study time and ESAP time	0.89 (<0.0001)	0.85 (<0.0001)	0.85 (<0.0001)
ESAP era	0.41 (0.0002)	0.23 (<0.0001)	0.23 (<0.0001)
Natural log of district-level change in spatial access to syringes distributed by an SEP since 1995	N/A	0.94 (0.09)	0.93 (0.08)
Change in district-level drug-related arrest rates per 1,000 adults since 1995	N/A	1.00 (0.67)	1.00 (0.68)
Natural log of spatial access to ESAP pharmacies	N/A	0.86 (0.002)	0.86 (0.001)
Percent of district residents who were non-Hispanic White decreased since 1995	N/A	0.86 (0.19)	0.86 (0.18)
Mean number of years since first injection	0.99 (0.20)	0.99 (0.24)	0.99 (0.23)
Non-time-varying district-level predictors			
Natural log of district-level	N/A	0.95 (0.004)	0.95 (0.003)

TABLE 3 Continued

Predictors	Model A growth curve model AOR (p value)	Model B “gradual decay” syringe access measure AOR (p value)	Model C “steeper decay” syringe access measure AOR (p value)
spatial access to syringes distributed by an SEP in 1995			
District-level drug-related arrest rate in 1995 per 1,000 adults	N/A	1.02 (0.06)	1.02 (0.06)
Interaction of the natural log of syringe access by drug-related arrest rates per 1,000 adults in 1995	N/A	0.99 (0.04)	0.99 (0.04)
Natural log of the percent of district residents who were non-Hispanic White in 1995	N/A	1.06 (0.25)	1.06 (0.24)

^aIntercept when the outcome is injecting with an unsterile syringe on >25% of injection events in the past 6 months

^bIntercept when the outcome is injecting with an unsterile syringe on ≥75% of injection events in the past 6 months

The magnitudes and directions of the relationships between the “steeper decay” syringe access measure to the outcome followed similar patterns to those described for the “gradual decay” measure (model C, Table 3).

DISCUSSION

Our analyses indicate that the relationship between spatial access to syringes and the odds of injecting with an unsterile syringe depends on local drug-related arrest rates. Specifically, in districts that had low drug-related arrest rates in 1995, injectors with better spatial access to syringes were substantially less likely to report frequently injecting with an unsterile syringe. In districts with no spatial access to syringes in 1995, injectors living in districts with higher arrest rates were more likely to report frequently injecting with an unsterile syringe. In districts where both of these exposures were present at baseline, spatial access to syringes somewhat buffered the harmful effects of these arrests (conversely, arrest rates attenuated the positive effects of syringe access). Additionally, our data suggest a trend in which increasing spatial access to syringes over time reduced the odds of frequently injecting with an unsterile syringe: the magnitude of the relationship between temporal changes in syringe access and the odds of injecting with an unsterile syringe was similar to the relationship between baseline syringe access and this outcome (AORs were 0.94 vs. 0.95, respectively). Greater statistical power is required to detect the relationship between time-varying exposures and outcomes than between time invariant exposures and outcomes.⁷⁴ While this analysis had over 4,000 participants, these individuals were distributed over 42 health districts and 12 years.

Des Jarlais and colleagues found that HIV incidence among injectors in NYC declined more than fourfold between 1990–1992 and 1999–2002, from 3.55 cases/100 person years at risk to 0.77 cases/100 person years at risk.⁷⁵ HIV incidence correlated strongly and negatively with the total number of syringes distributed by NYC-based SEPs during these years ($r=-0.99$).⁷⁵ The present analysis echoes these

findings at a smaller geographic scale, and brings into focus the behavioral mechanisms driving part of this correlation.

Our findings support the conceptualization of SEPs as structural interventions that alter the contexts in which injectors use drugs. In our analyses, the relationship between spatial access to syringes and the odds of injecting with an unsterile syringe was not stronger among individuals who reported going to an SEP in the prior 6 months. While our measure of direct SEP participation was crude (e.g., it did not capture frequency of going to an SEP), our results are broadly consistent with other studies that have found powerful SEP effects on the risk behaviors of non-SEP-participants who acquire sterile syringes via secondary and satellite exchange.^{19,23} One interpretation of our findings is that injectors' secondary and satellite exchange efforts were sufficiently successful at increasing the flow of sterile syringes into NYC UHF districts that SEP participants and non-participants were equally likely to inject with a sterile syringe.

Our analyses also suggest that SEPs' effects were strongest in the areas surrounding the SEPs. Stronger local effects may have been produced by two processes. First, as Williams, Rockwell, and others have found,^{24–26} individuals who live closer to an SEP site are more likely than other injectors to go to an SEP and to inject with a sterile syringe. Second, injectors' drug use networks may be relatively contained within their residential neighborhood,²⁷ and thus many syringes distributed through secondary exchange efforts may not travel far from the original SEP source. By their very nature, satellite exchange efforts should counter this spatial concentration. We did not know the number of syringes diverted to other areas via satellite exchange, nor did we know the location of satellite sites. As a result, we likely underestimated the number of syringes flowing into districts with no or poor SEP access and overestimated the number of syringes flowing into districts that had SEPs. Notably, we were still able to detect SEPs' local effects, despite this systematic misclassification.

An injector's spatial access to syringes within the UHF district where he or she resides is a function of at least two factors: the geographic location of SEP sites and the volume of syringes flowing from these sites. Though concerns that SEPs increase crime rates and exposure to discarded syringes are unfounded,^{76,77} the location of SEP sites remains controversial.^{2–4} Our results support past research that has found that the presence of an SEP in a geographic area reduces HIV risk behavior among local residents who inject;^{24–26} moreover, we find that this benefit extends to injecting residents who do not personally go to the SEP site.

The volume of syringes flowing from SEPs is determined, in part, by municipal and state policies regulating syringe distribution by SEPs.⁷⁸ These policies can restrict the number of syringes that can be given to any one person during a visit, and can mandate one-for-one exchange.⁷⁸ Participants who attend SEPs with more restrictive distribution policies are more likely to re-use syringes, and have lower syringe coverage;^{78–80} poor syringe coverage has, in turn, been associated with higher odds of receptive syringe sharing, distributive syringe sharing, and syringe re-use.⁸¹ While we could not measure syringe coverage, our analyses indicate that getting more syringes into circulation in NYC UHF districts is protective for local injectors. Distribution policies that reduce this volume may impede injectors' risk reduction efforts.

Our finding that drug-related arrest rates eroded SEP effects is broadly consistent with findings from a growing body of research on the ways that drug-related law enforcement activities imperil users' health and SEP operations.^{31–41} Notably, however, some past research suggests that SEPs are able to maintain the volume of

syringes they distribute during police drug crackdowns, though the number of injectors going to the SEPs declines.^{82,83} Our findings suggest that sustaining the volume of syringes flowing into communities when drug-related enforcement activities intensify is not enough; drug-related arrests appear to hinder injectors' ability to actually use these syringes. When enforcement activities escalate, injectors may not carry syringes to their injection site in order to reduce their risk of being identified as a user during a police search.^{31,32,34,35,84} Additionally, the ability of secondary exchange networks to relay sterile syringes through communities may be damaged when a network member is arrested or incarcerated.

As reported elsewhere, increasing spatial access to ESAP pharmacies was associated with reduced odds of frequently injecting with an unsterile syringe.²⁵ This district-level phenomenon, however, did not modify the relationship between syringe access via SEPs and our outcome, though research suggests that many injectors in NYC now acquire syringes through ESAP pharmacies.⁴² We note that our measure of ESAP access did not capture the volume of syringes sold by pharmacies. Had we been able to capture variations in syringe sales across time and space, our analyses might have detected an interaction between syringe flow from SEPs and from ESAP pharmacies.

The relationship of spatial access to syringes with the odds of frequently injecting with an unsterile syringe did not vary across racial/ethnic groups. This finding contrasts with that of Williams et al., who found that the magnitude of the relationship between distance to an SEP and RSS was greater for Latino injectors than for Black or White injectors.²⁶ It may be that we found no racial/ethnic differences in our analyses because secondary and satellite exchange efforts channel syringes to members of racial/ethnic groups who are less likely to personally attend SEPs.

Our findings should be interpreted in light of several limitations. Research into spatial access to SEPs is new; to our knowledge this is the first attempt to model syringe flow from SEPs and investigate its relationship to injection practices. Future research should consider making several refinements to the present syringe access measure. Our measure assumed that all syringes were distributed within 1 mile of the SEP source; future measures may experiment with a range of buffer sizes. We experimented with two decay formulae. These formulae, however, produced relatively similar distributions of syringes across space. This similarity likely accounts for the identical findings that we reached using these two measures. Future research may experiment with a broader array of decay formulae. As noted above, our measure of syringe access ignored secondary and satellite exchange; it also ignored underground exchanges and public transportation routes. These last limitations likely biased inferential findings to the null. Future research should follow the lead of Williams et al.'s work on spatial access to program sites and incorporate users' "activity spaces" (e.g., places where they use drug, buy drugs, and work) when considering spatial access to syringes.²⁶ Ideally, our models would have incorporated local demand for syringes (i.e., the number of injection events occurring in each district annually). Data needed to estimate demand are simply not available for such small geographic areas.

Additionally, this is a serial cross-sectional analysis. We attempted to control for compositional changes in the Risk Factors sample over time, but these controls may have been incomplete.

Considered in conjunction with past research, our findings suggest that policies that curtail spatial access to sterile syringes—whether by restricting locations where SEPs operate, or limiting the number of syringes SEPs distribute to individuals—

impede injectors' capacity to reduce drug-related harms. Our finding that drug-related enforcement efforts targeting drug users make it difficult for them to actually *use* sterile syringes flowing into their communities lends further support to numerous calls to shift these enforcement efforts away from drug users.

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